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Practical Recommendations for Regional Sediment Management: Lessons Learned as part of the Niobrara River Basin Initiative

by Paul M. Boyd

PURPOSE. This Coastal and Hydraulics Engineering Technical Note (CHETN) provides a summary of the Niobrara River Basin Regional Sediment Management (RSM) Initiative, along with the identification of programmatic lessons learned and recommendations for future application of RSM strategies for similar projects.

INTRODUCTION. RSM is in the early stages of integration into the management of many inland river systems. Even with little ongoing dredging in support of navigation, opportunities still exist here for beneficial use of these dredged material. Seeking opportunities to assist Flood Risk Management, improving the environment, and managing sediments before they must be dredged adds significant benefits to Federal projects. Reducing sedimentation can reduce US Army Corps of Engineers Operations and Maintenance (O&M) expenses, and positively impact projects' ability to meet their authorized purposes. Integrating RSM concepts to management of the Niobrara River will serve to benefit all of the current project purposes. While this is a departure from the typical approach to RSM in the coastal setting, it holds considerable promise in riverine areas in that it may prevent the delivery of excess sediment to coastal areas.

NIOBRARA RIVER BASIN INITIATIVE. The Niobrara River drains the sand-hills of northwest Nebraska and South Dakota. The Niobrara River Basin is 355 miles long and encompasses an area of 13,000 square miles. Land use within the basin is primarily agricultural (ranching and farming), and there are only minor impoundments on the main stem. Development within the basin has been primarily related to center pivot irrigation.

The Niobrara River joins the Missouri River in northeast Nebraska near the village of Niobrara (Figure 1). The confluence is just upstream of the headwaters of Lewis and Clark Lake, which is the most downstream reservoir on the Missouri River main-stem system. The Niobrara River supplies over half the sediment load that enters Lewis and Clark Lake. The resultant delta causes: increased surface water flooding; problems related to groundwater levels, water quality, and water supply for municipal water intakes; recreation access problems; and adverse impacts to endangered species habitat. Cities, counties, landowners, and local businesses, and also the Santee Sioux Tribe have all expressed interest in managing Niobrara River sediment.

RSM Goals. The US Army Corps of Engineers RSM strategy is a watershed-scale problem solving method designed to find environmentally and economically sustainable solutions to sediment-related problems (US Army Corps of Engineers 2004). The RSM strategy has adopted a large-scale approach in recognition of the fact that attempting to solve sediment problems at local scales alone is not only likely to be unsuccessful, but may exacerbate the sediment problem at other locations. These RSM goals were applied in this Niobrara River Basin Initiative.

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Figure 1. Niobrara River confluence with the Missouri River (photo 2005).

For the Niobrara River basin, changes in river use (construction of Missouri River dams) and land use have caused the need to examine impacts of these changes. In many ways, the Niobrara is a victim of the external changes in the Missouri River basin. The river functions similarly to its historic process, but can no longer maintain its historic planform.

Simply moving sediment at the mouth of the Niobrara down the Missouri River only addresses a local problem. Until sediment loading to the Missouri is either reduced or transported below the reservoir system, it cannot be said that there are regional benefits to the action.

The Niobrara River Basin Initiative is a basin-wide sediment yield analysis to: (1) identify the various sources of sediment (main-stem, tributaries, etc.), (2) determine if the contributions from the various sources are changing over time and, if so, determine if these changes are due to natural events or man-induced factors, and (3) ascertain the impacts of basin-wide sediment management practices on the main stem of the Niobrara River as well as on the total sediment yield from the basin. Information developed from this initiative will be used to determine the feasibility of managing sediment from the Niobrara River Basin to reduce impacts to Lewis and Clark Lake, and to serve as a model for RSM activities elsewhere in the Missouri River Basin.

RSM Strategy. The Niobrara River Basin Initiative was completed in three phases (Phase I, Phase II, and Phase II Supplement), and involved the following work items:

- Coordination and collaboration with the US Department of Agriculture Natural Resources Conservation Service (NRCS), and with the local Natural Resources Districts (NRDs)
- Literature review of applicable information
- Development of a detailed initiative plan
- Collection and analyses of relevant sediment budget data, and appropriate alternatives
- Evaluation of alternatives and development of RSM guidance for the Niobrara River.

Existing data were used as much as possible, and the basin was broken into representative sub-areas for detailed analyses. Phase I, Phase II, and Phase II Supplement were conducted as part of this RSM effort. (An additional phase to implement the recommendations of Phase II may be completed in the future.)

Phase I (Ayres and Associates 2008). The NRCS and the NRDs were solicited for their information, insight, and expertise. Their contributions to the initiative included historical data, history of management practices, and current sediment control practices. Using guidance from the NRCS and NRDs, as well as from the US Geological Survey (USGS), numerous agency and university data bases were researched to obtain historic data and past studies. The information developed through these efforts by Ayres and Associates (2008) was used to finalize the Scope of Work for Phase II.

Phase II (WEST Consultants 2010a). Extensive data were collected from the NRCS, the USGS National Water Information System (USGS-NWIS), the USGS Nebraska Water Science Center (USGS-NWSC), the Nebraska Department of Natural Resources, interviews with dam operations personnel, and numerous published Niobrara River field studies. These data included existing land use, soil gradation, and erosion factors, and also detailed historical stream-gage records of river geometry, measured stages, water surface elevations, and flows.

A sediment transport analysis by WEST Consultants (2010a) found that the upper portion of the Niobrara River is aggrading, the middle section is essentially stable, and the lower portion is degrading (Figure 2). Sediment transport analyses revealed that net sediment outflow from the Niobrara River has decreased from a historical peak of 2.9 million tons per year to a present flux of about 1.8 million tons per year (Figure 3). It is not clear if this decrease is due to natural events or man-induced factors.

A Revised Universal Soil Loss Equation (RUSLE) analysis found that 80% of sediment exported from the Niobrara River Basin is delivered from channel bank or bed erosion; the remainder is delivered from overland erosion processes (e.g., sheet/rill or inter-rill).

Phase II Supplement (WEST Consultants 2010b). Given the information from Phase II, a supplement Scope of Work was prepared to expand the stakeholder database and further consider specific RSM actions.

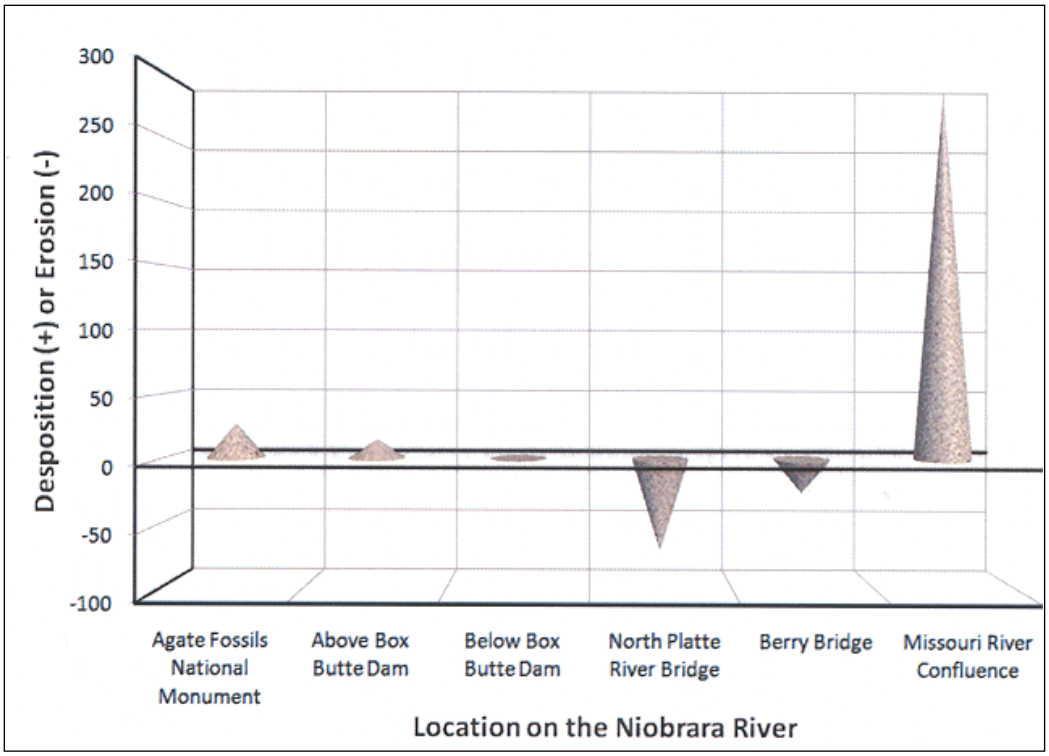

Figure 2. Annual deposition and erosion in 1,000 tons/year, Niobrara River, Nebraska and South Dakota (after WEST Consultants 2010a).

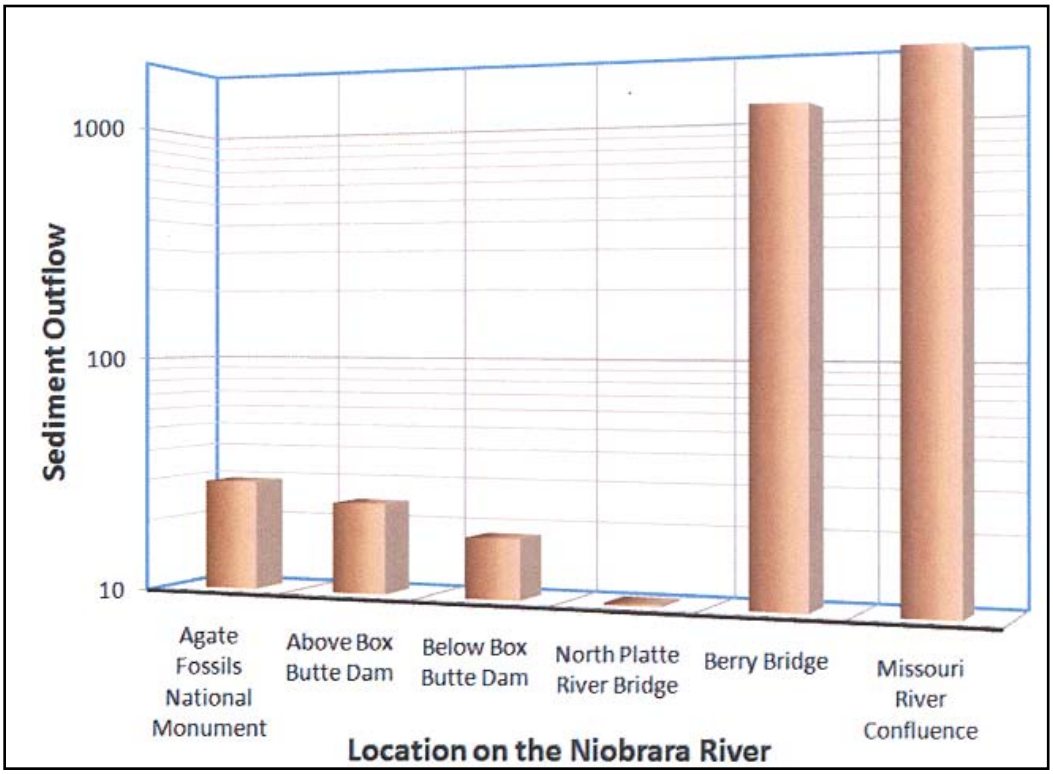

Figure 3. Sediment outflow in 1,000 tons/year, Niobrara River, Nebraska and South Dakota (after WEST Consultants 2010a).

More than 70 stakeholders were identified by WEST Consultants (2010b) through extensive dialogue with Missouri River Futures (www.missouririverfutures.com) as well as internet and literature search. Stakeholder opinion, solicited by survey, is that flexibility, communication, public outreach, and sensitivity to local issues are essential RSM strategy components. Stakeholders reported a number of successful sediment management actions with the most promising being grade stabilization, cedar revetment with planting, buffer zone creation, and irrigation capture. These methods were then evaluated as potential watershed-scale RSM strategies in terms of two goals: (1) Basin-wide sediment reduction (reduce sediment along the entire river), and (2) Sediment flux control (reduce net sediment outflow to the Missouri River).

The latter approach considers only measures applied to the lower portion of the Niobrara River. Dredging was also considered as a method to reduce or even mitigate annual sediment outflow from the Niobrara River into the Lewis and Clark Lake. The dredged material could be used to create new, usable land within the available areas of the delta.

Approximate cost/benefit ratios were developed to account for not only the directly measurable benefits of sediment reduction such as decreased flooding risk, but also the less tangible benefits as well. The ratios were developed by researching public response to previous RSM efforts, from which a numerical benefit of sediment control was inferred. This approach, while approximate, accounts not only for quantifiable benefits but also for societal benefits and perceived values of the ecological and environmental benefits (WEST Consultants 2010b).

Two separate objectives were considered for the analysis. The first is **comprehensive sediment control,** referring to a goal of reducing sediment outflow throughout the entire Niobrara River. The second, noted here as **net sediment control,** refers to a plan that reduces or eliminates the net sediment outflow of the Niobrara River, but may not change sediment conditions along the Niobrara River.

RSM strategies for comprehensive sediment control. Figure 4 shows the cost/benefit ratios, and overall costs and benefits, for all possible sediment strategies for comprehensive sediment control. Many strategies were found to have cost/benefit ratios greater than 1. The combined method of creating buffer zones, capturing irrigation outflows, and dredging the remaining sediment has the highest cost/benefit ratio of any approach that fully captures the net sediment runoff from the Niobrara (maximum benefit).

RSM strategies for net sediment control only. Using all available methods may be the best approach to achieve net sediment control only. With this option, the need for dredging is very small; only a small portion of the available delta storage would be required.

The costs and benefits of these options, while only approximate, indicate that there are a number of potentially successful approaches that can be considered for implementation (Figure 5).

The key conclusion of this analysis is that, when developing an RSM plan for a complete river basin (large or small), multiple factors play into the current condition. Therefore, multiple factors often have to be addressed to correct the sediment imbalances in the system.

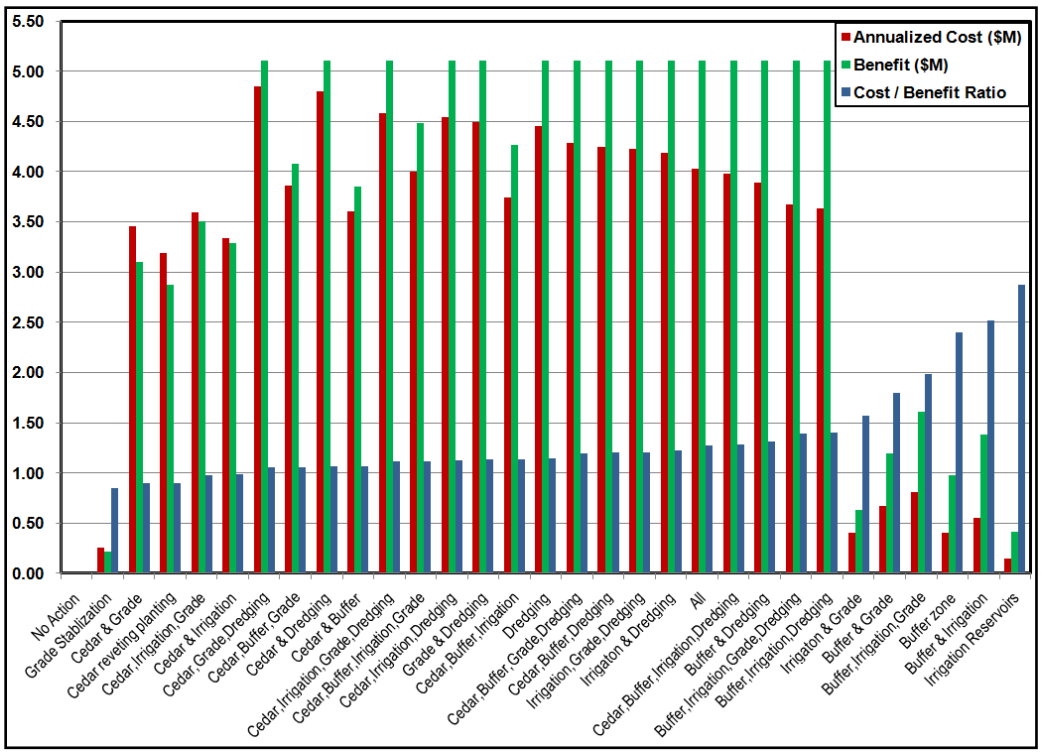

Figure 4. Cost/benefit analysis of comprehensive sediment control strategies, Niobrara, Nebraska and South Dakota.

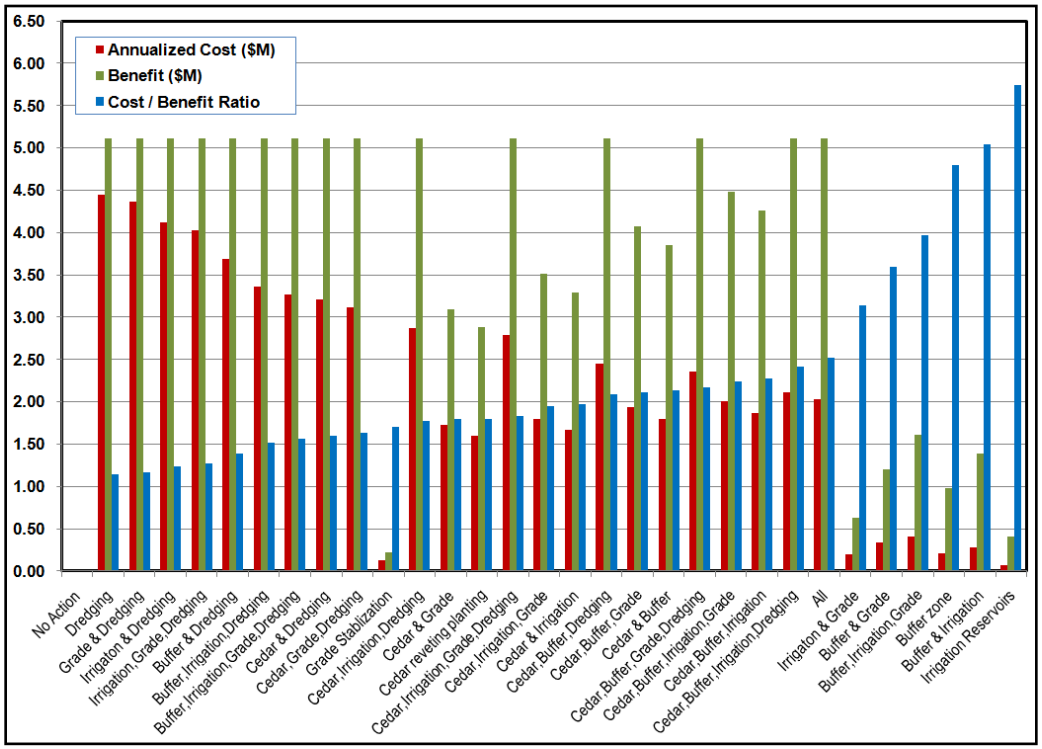

Figure 5. Cost/benefit analysis of net sediment control strategies, Niobrara River, Nebraska and South Dakota.

NIOBRARA RIVER BASIN INITIATIVE CHALLENGES. A number of challenges surfaced throughout the process of identifying the contributing factors to sediment imbalance, creating a sediment budget, and developing strategies to address the current problems:

- In highly regulated river systems, the impact of main-stem management on tributaries can be difficult to overcome. If it were not for the hydrologic conditions on the present day Missouri River, there would likely be less sediment deposition at the mouth of the Niobrara River.
- River basins with low population and few resources yield low data availability. Suspended sediment data on the Niobrara River is almost non-existent. Sediment collection at gages is uneven and irregular, and nowhere did a continuous record exceed a few years. One of the goals of this initiative was to develop a good sediment budget to assess sinks and sources. While this was completed, it was done through surrogate methods, soil loss estimations, and gage rating curve trends, in addition to the occasional sediment sample.
- Competing river uses often polarize landowners, marine operators, management agencies, and taxing authorities on issues associated with changes in the current river use. Consensus is not easily achieved when discussing change, and that has been found to be the case when discussing strategies to manage sediment on the Niobrara River. Many of the recommended activities developed during the Phase II Supplement process have been met with significant resistance in the basin. To this end, it is valuable to identify a large suite of possible actions, as it is likely that many of them cannot be fully implemented.

GENERAL RECOMMENDATIONS FOR PRACTICAL APPLICATION OF RSM. Three actions are vital to the application of RSM in upland river projects:

- Identify the need for RSM early in the planning process. Often, RSM is applied to a project after a plan is approved and ready to be implemented. While it is almost always valuable to apply RSM concepts to a project, identifying that value early can alter the direction and the end product.
- Ensure that a team member represents RSM goals and processes throughout the project. In follow-up to the first action, a team member must represent RSM ideas throughout the project process. This effort aids in preventing the “RSM at the last minute” situation.
- Develop communication lines early and solicit solution input. Experience with the Niobrara River Basin RSM strategy has shown that solutions and recommendations provided by stakeholders are often better received than those developed by management agencies. The actions suggested by USACE as part of the Phase II survey were well received, but not as well as those suggested by stakeholders. The local people living in the region often have the best solutions. It is in the best interest of all involved to have an amicable agreement, and this can be more easily achieved by relying on recommendations and suggestions of the local populous.

CONCLUSIONS. This Coastal and Hydraulics Engineering Technical Note (CHETN) provides a brief overview of RSM as it was applied to the Niobrara River Basin Initiative. Challenges experienced during this project were investigated to help develop practical recommendations that will improve RSM applications at other USACE projects. Continued effort is required to fully integrate RSM on inland river projects.

ADDITIONAL INFORMATION. This CHETN was prepared as part of the Regional Sediment Management (RSM) program, and was written by Paul M. Boyd, US Army Corps of Engineers Omaha District, Omaha, NE. Information presented in this CHETN is based on interviews with Omaha District personnel as well as published reports on the subject. Additional information pertaining to RSM can be found at the RSM web site http://rsm.usace.army.mil

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WEST Consultants. 2010b. Regional sediment management demonstration project, Niobrara River Basin, Nebraska and South Dakota; Phase II Supplement. (report prepared for US Army Engineer District, Omaha, NE.)

ACRONYMS AND ABBREVIATIONS.

Term	Definition
CHETN	Coastal and Hydraulics Engineering Technical Note
CHL	Coastal and Hydraulics Laboratory
ERDC	Engineer Research and Development Center
HQUSACE	Headquarters, US Army Corps of Engineers
NRCS	Natural Resources Conservation Service
NRD	Natural Resources District
NWIS	National Water Information System
NWSC	Nebraska Water Science Center
O&M	Operations and Maintenance
RSM	Regional Sediment Management
RUSLE	Revised Universal Soil Loss Equation
USACE	US Army Corps of Engineers
USGS	US Geological Survey